

SCIENCE PRIMER

BOOK I

FOR STANDARD VII

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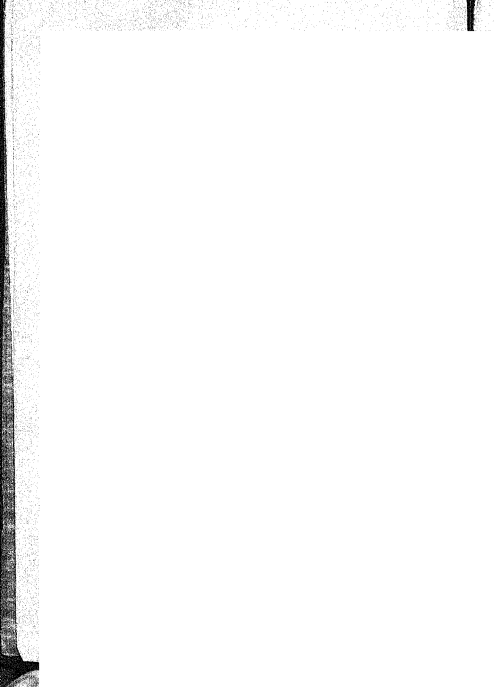
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Presented to the
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SCIENCE PRIMER

I. WHAT IS PHYSICS?—(1)

The word Science really means knowledge, and so Natural Science means knowledge of nature, or of things which occur in this great world in which we live. As there are very many different kinds of things in our world, so there are many different branches, or kinds, of Natural Science. Thus we have Botany, which is the science of plants, Geology, which is the science of the rocks and soil, and Zoology, which is the science of animals. These three are easy branches to define, but it is not so easy to define the sciences of Physics and Chemistry.

Physics.—Let us take physics first. The word physics comes from a Greek word, which means *nature*, and so physics, or physical science, means knowledge about things and events in the world around us. This knowledge we gain by our senses

of sight, hearing, touch, smell and taste. In physics the first three of these senses are the most important.

If you look about you and notice carefully the things you see and hear and feel, you will soon find that many of them are really very strange and wonderful. You will find them still more wonderful if you ask yourself two questions. The first question is "how?" and the second is "why?"

For instance, look at the sun in the evening. It seems to dip down into the earth, but you know that it will rise again to-morrow. *How* does the sun rise and set?

Again, *why* does the bright part of the moon change its shape day by day, and *why* does a stone fall to the ground again when you have thrown it high into the air? These are strange events, and you probably do not know the cause of them. Perhaps you have never even thought about them. Physics is the branch of science in which we learn about the things which we see and hear and feel around us, and which attempts to answer these two questions "how" and "why" with regard to them.

II. WHAT IS PHYSICS ?—(2)

Observation.—When we use the senses of seeing, hearing and feeling, and carefully note what we see and hear and feel, we are said to make observations. In order to study physics it is necessary to practise the power of observation. You must note everything that goes on about you and let nothing escape your notice, and you must always keep asking yourselves the questions “how?” and “why?”

You will never be able to learn physics from a book, as you learn arithmetic or history. In arithmetic and history there are no things for you to see and hear and feel, and so they can be learnt from a book. To learn physics you must make a practice of observing everything you see, and try to find out the reasons for the facts you observe.

Perhaps you think it is very easy to make observations. If you do think so you are mistaken. You have seen the rainbow many a time, have you not? Yet you will soon find that you know very little about it. You probably know that it is formed when the sun is shining on a rainy day, and that it looks like a big bow in the sky, but

can you tell whether it is truly circular or not? Can you tell how many colours there are in the bow, or what the names of the colours are, or in what order they are arranged? Do you know that when you face the rainbow, the sun is always at your back? Have you noted that there is nearly always a second rainbow higher up in the sky which is not so bright as the lower one?

Next time you see a rainbow, make observations of all these facts. When you can make observations correctly you may begin to try to find out explanations of what you observe.

Physics is sub-divided into (1) **Dynamics**, which treats of motion in general; (2) **Astronomy**, which treats of the motions of the earth, the moon, the planets, the sun and the stars; (3) **The properties of Matter**; (4) **Sound**; (5) **Heat**; (6) **Light**; and (7) **Electricity and Magnetism**.

III. WHAT IS CHEMISTRY?

We have seen that physics is the knowledge of things and events in the world around us, and that we gain this knowledge by making observations accurately, and explaining what we hear and feel and see. Let us now try to define the meaning of "*Chemistry*."

We may first say that *Chemistry is the study of all kinds of substances*; but here we have the word "substance," and we must make quite sure that we know what that word "substance" means.

Let us consider something that is quite common in India, an ordinary cooking pot. Can we call a cooking pot a substance? No, a cooking pot is made of copper, and copper is the substance of which it is made. To find out whether anything is a substance or not, we may ask the question "what is it made of?"

Is a table a substance? No, it is made of wood. Is wood a substance? Yes; it grows as wood, and we cannot break or cut it up into anything which is not wood. Wood is the substance of which the table is made. Is a *gharra* a substance? No; it is made of clay. But clay is a substance, because if we break up a lump of clay into small pieces, each piece is still clay as it was before. The fragments are only smaller pieces of clay.

Now, there are a very great many different substances in the world. Let us mention a few. We have iron, lead, copper, chalk, lime, sulphur, charcoal, paper, wood, glass, air, water, straw and hundreds and hundreds of others.

Some of these substances are formed from other quite different substances; some will easily join

together and form new substances, and sometimes one substance can be split up into several different substances. **Chemistry** is the science which teaches us about substances, and how they behave towards one another.

You will find the behaviour of substances very interesting, and it is also very important. If wise men had never studied how substances behave, we should never have had such things as iron, brass, glass, paper, and countless other substances, which have now become quite necessary to us every day.

IV. WHAT IS MATTER ?

The universe is the name given to all space, and the earth, the sun, the moon, the planets and stars which fill it.

All the stuff which there is in the universe is called **matter**. The earth and the sun are matter, so are the stars, and everything else which makes up the universe.

We recognize matter by our senses of sight and touch; for example, we can see a table and touch it, and we know that it is made of wood; we can see the walls of the room and touch them and know that the walls are made of bricks. Now matter is

the name given to all the different kinds of stuff of which all things are made, so we know that the table and the walls of the room must be matter.

We cannot hear matter, although we can nearly always see, or feel it. We can only hear sound, which is not matter. There are some kinds of matter which we cannot see; for example, we cannot see air, but we can feel it. Then there are some kinds of matter which we can see but cannot feel; we cannot get close enough to the moon and stars to touch them, but we can see them, and we know that they must be matter, because they behave so much like other forms of matter, such as this earth.

Perhaps you would now be ready to say that light and heat are two kinds of matter. You would say that we can see light and we can feel heat. True, but what are light and heat *made of*? To that question we should have to reply that light and heat are not made of anything, and so light and heat cannot be matter.

(The best and safest way of finding out whether anything is matter, or not, is to find out whether it has weight.) You will learn later on that all matter has weight, and that everything which has weight is a form of matter. Heat and light cannot be weighed. A thing has just the same weight when it is hot as when it is cold. A body

weighs just as much in the dark as it does in the sunlight. Neither heat nor light have weight and so they are not matter.

Since matter is all the stuff in the world, matter must be made up of the substances which the world contains. Substances differ from one another very much, but "**matter**" includes all of them. The amount of matter in the world always remains the same. We cannot make or destroy matter, and so it is said to be indestructible. This does not seem true to you at first. You think that you can dry up water, or burn up wood, and so destroy it. But your physics and chemistry will teach you that when water dries up nothing is destroyed, and that when wood is burned new substances are formed which weigh just as much as what was burned up. The quantity of matter in the wood and water cannot be changed.

V. PROPERTIES.

We have already seen that in order to study science properly, it is necessary to learn how to make correct observations. The simplest observations to make are observations of the properties of substances.

Before we try to make observations we must learn what this word **property** means.

If you try to describe a substance, what do you say?

Take copper as an example. - You would say:—
 "Copper is a metal, it is heavy, it is hard, it is red, it can be hammered into different shapes."

You cannot think of copper at all unless you think of a hard, red, heavy metal which can be hammered into different shapes. These qualities of hardness, redness, heaviness, the quality of being metallic, and malleable,* are the properties which belong to the substance copper.

You see then, that a property is not a "thing." But you cannot think of a property unless you think of a thing, or substance, to connect the property with. For instance, you cannot think of redness unless you think of something that is red. You cannot think of heaviness or hardness unless you think of things that are heavy or hard.

You cannot think of any property in the same way that you think of things which you can touch or see. Properties are not matter, they are the qualities which belong to matter.

You will understand this better if you think of what are called "*abstract nouns*," such as goodness, kindness, and so on. Goodness and kindness are qualities of good and kind men. We can only

Malleable means can be hammered into different shapes.

think of goodness and kindness, when we think of good and kind people. It is just the same with properties.

Of course, you can easily see that any substance must have many properties, just as copper has. To describe a substance properly we have to consider *all* its properties. This can only be done when we know how to find out what its properties are.

When you know all the properties of a substance you know all about that substance which it is possible to learn.

VI. SOME SIMPLE PROPERTIES.

Now let us make a few simple observations of the properties of some common substances.

Place on the table before you some pure cane sugar, and some ordinary salt. What can you say about the properties of sugar? First look at the sugar and note its colour. Sugar is *white*. Then you see at once it is a *solid*.

Then taste it. Sugar is *sweet*.

Thus, three properties of sugar are whiteness, solidity and sweetness.

Put some into a glass with some water and stir it up. It dissolves and gives the water a sweet taste. Sugar *dissolves in water*.

Notice the shape of the separate grains of the sugar. They are quite regular, and all the grains have the same shape. These regular shapes are called *crystals*. Sugar forms *crystals*.



Hammer some of these crystals with a hammer. They break up into powder. Sugar is *easily broken up into powder*.

Set fire to a heap of this powder. It burns with a bright flame. Sugar *will burn*.

We learn then, from our observations and experiments, that sugar has the properties of whiteness, solidity, sweetness, of dissolving, of being crystalline, of being easily broken and of burning. When we put all these properties together and think of a substance which has all these properties, we find that we are thinking of sugar. In other words, we have described sugar.

In the same way you will find that salt has a taste which we describe as *saltish*; it, too, is a *solid* which *dissolves in water*, and it forms *crystals*. It can be *broken up into powder* easily, but it *will not burn*.

These observations teach us some of the properties of salt. We cannot think of salt without

thinking of these properties, and we cannot describe any substance until we can make correct observations of its properties.

Exercise.—Write down some common properties of slate, lead, silver, water, air.

VII. COMMON PROPERTIES—HARDNESS.

Hardness.—We will now examine some of the properties of common things such as we see every day.

First let us take hardness.

How to measure hardness.—Collect some pieces of glass, slate, lead, iron or steel, copper, wood, wax, chalk. They look very different, do they not? They have many different properties. They differ in shape, colour, taste and combustibility, and now you will soon see that they differ in hardness as well.

Take up the piece of iron or steel, (a pen-knife will do nicely) and try to scratch the glass, the stone, and the copper with it. You will find that you can easily scratch the copper, but not the glass. Next try to scratch the iron with the glass. You perhaps will be surprised to find that you can scratch the iron with it. You see then, that glass is harder

than iron, iron harder than copper ; copper, again, you will find, is harder than slate, slate harder than wood, wood harder than chalk, and wax is softest of all.

Substances differ, as you see, in their property of hardness just as much as in colour, or taste, or indeed in any other property. Hardness is one of the properties by which we can recognize a substance.

(1) *Find out which of the things you have collected are harder than your finger nail and which are softer.*

(2) *Arrange the following things in order of hardness, the hardest first and then the next hardest, and so on :—lead, cork, horn, bone, rock^{frag}salt, brick, chalk, copper, steel, slate.*

Note.—Each pupil should do these experiments by himself, and then all the lists should be compared and corrected.

VIII. MORE COMMON PROPERTIES—(1).

There are many more properties of substances about which it is necessary to learn something. The best way to do this is to take a few common things and see what we can find out about them.

Get some small pieces of glass, roll-sulphur, lead,

blotting paper, india-rubber and cane, and a glass of water : place them before you on the table. Take up the piece of glass first. You notice that you can see through it. What else is there on the table through which you can see? Only the water. All things through which you can see are said to be transparent. Glass, air and water are transparent. Things through which you cannot see are said to be opaque. Wood, lead, sulphur, and paper are all opaque.

Things that can easily be broken are said to be brittle.

If you hit the piece of glass with a hammer or stone, it will break into smaller pieces. So will roll-sulphur. They will also break if we drop them on to a hard floor. Things which break into pieces, like glass, or baked clay, (such as a *gharra*) are said to be brittle.

Other things do not break when they are hammered, but they can be beaten till they get quite thin and become sheets. Lead can be beaten out into sheets in this way, so can gold and copper. Such substances are said to be malleable. Gold is the most malleable of all substances, but lead is very malleable too, and if you keep hammering a piece of lead, you will find that you can make it almost as thin as a sheet of paper.

Gold is so malleable that it can be hammered out into sheets so thin that 1,00,000 of these sheets placed one on the top of another would only make a heap 1 centimetre thick.

IX. MORE COMMON PROPERTIES.—(2).

Take up a sheet of lead ; you see that you can bend it very easily, when you take away your hands from it, it keeps the shape into which you had bent it. So will a piece of copper. Things which can be bent into any position or shape, and which keep that shape are said to be **pliable**.

If you bend a piece of india-rubber, it will regain its original shape as soon as it is free to move. So will the blade of a good steel penknife, or a sword, or a strip of bamboo, or cane. Such things are said to be **elastic**.

Examine the following things and see whether they are pliable or not :—

Tin, zinc, soft iron, bamboo, brass, steel, india-rubber.

Some of these things, you will observe, do not keep the shape into which you bend them. They are not pliable, but they spring back into their first shape as soon as you allow them to do so. All those are elastic.

One very elastic thing is common air. Get hold of a bicycle pump and close up the end which screws on to the valve of the bicycle. You may do this by means of your finger, or by a small piece of india-rubber, or cork. Then push down the handle of the pump and let go of it quickly. It will not stay down but will rise up again. The air in the pump had been squeezed, or pressed together, but it regained its shape as soon as you allowed it to do so.

Another way of showing that air is elastic is to take two test tubes, one of which just fits inside the other. Put a few drops of oil or water on the outside of the smaller tube; then force it down into the larger one. The water will prevent any air from escaping, and as soon as you release the tube which has been forced down, it will rise again to its first position.

Questions.—Can a thing be both pliable and elastic, or pliable and brittle, or brittle and elastic?

Write out lists of things which are malleable, pliable, brittle, transparent, elastic, etc.

X. MORE COMMON PROPERTIES—(3).

Solubility.—Next let us take the property of dissolving, or solubility. Get three glasses, some sugar, alum and sand, and put them before you on

your working table. Then follow these directions carefully.

First powder the sugar and alum, and then measure out equal quantities of sugar, alum and sand in a measuring glass, and put each of these measured substances into a different glass. Then pour into each glass ten times as much water as you took of the substance. Then stir up the contents of each glass with a glass rod.

Note carefully what happens.



The sugar soon disappears altogether, a little of the alum seems to have gone, but the sand will not seem any less than it was at first. If you taste the water in the glass which held the sugar, you will find it is very sweet, the water from the second glass will taste bitter like alum, but the water in the third glass will have no taste at all.

Although you cannot see the sugar any longer, it is still in the glass. It has dissolved in the water,

and we now call the contents of the glass a solution of sugar in water. The sugar is said to be soluble in water. The property of dissolving is called solubility. Alum is much less soluble than sugar, while sand is not soluble at all. Things which do not dissolve are called insoluble.

Most substances are more soluble in hot water than in cold water, so that to dissolve a substance quickly it is better to use hot water than cold.

You see then, that substances differ very much in this property of solubility. It is one of the properties which help us to recognise substances.

Which of the following are soluble and which are insoluble?—Salt, chalk, copper, wax, charcoal, borax. Find out, for the present, by the taste and appearance of the water. You will learn more about solubility in a later lesson.

XI. SOLUBILITY.

Nothing lost when substances dissolve.—When a solid dissolves in a liquid, it *seems* to disappear. You know that the solid is really present in the liquid, because if the water is boiled away the solid is left behind.

Weigh out two or three grams of finely powdered nitre. Then weigh a flask containing about twenty

or thirty c. c. of warm water. Now put the nitre into the water. Gently shake the flask till the nitre has dissolved. Then weigh the flask again. The weight is now that of the flask and water *plus* that of the nitre. The total weight of a solid and liquid remains unchanged when solution takes place.

Perform the same experiment with sugar and with salt. In all cases nothing is lost when a substance dissolves.

XII. POROUS THINGS.

Take a small piece of cane and cut it across. Look carefully at the part which you have cut. It seems to have a great many little holes. Put the cane under a magnifying glass. The little holes are now quite easy to see.

Examine a piece of charcoal in the same way. It, too, seems to have a great many little holes. These little holes are called pores, and things which contain a great many little holes, such as cane, are called porous.

If you take a strip of blotting paper and dip one end of it into a blot of ink, what happens? The ink is soaked up by the paper. Blotting paper is porous, and the ink goes into the pores of the blotting paper.

We can show that blotting paper is porous in another way.

Cut out a circular piece of blotting paper. If you fold the blotting paper across the middle and then across the middle again, you can make a sort



of little cup. This is called a *filter*. Now pour a little water into the filter; you see it soon begins to pass through the little pores of the paper. The blotting paper is porous. Glass is not at all porous neither is copper, nor lead nor silver.

In blotting paper the little pores are so small that although water can pass through them, solid things cannot pass through. For instance, take some chalk and grind it into a fine paste with a little water. This is best done by means of a pestle and mortar such as is shown in the diagram. Then mix up the white paste with more water in a beaker, till the mixture looks like milk.



You have learned how to fold a filter paper.

Fold one and fit it into a glass funnel.

Wet it with water

and press the paper

against the sides of

the funnel. Now

pour the chalk and

water into the filter

and collect what

passes through in a

glass vessel. It will

be a clear liquid.

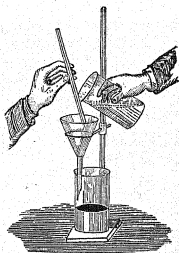
The water can pass

through the pores of

the filter, but the

solid chalk remains

behind. The clear liquid is called the *filtrate*.



Charcoal is a porous substance and is often used to filter drinking water. It allows the water to pass, but dirt and dust, which have fallen into the water, cannot pass through.

What is a funnel? What is a filter paper? What is filtrate?

XIII. MORE ABOUT SOLUBILITY.

We have already found that some things dissolve in water and that others do not. We also saw that of soluble things some are much more soluble than others, and we found that, when a substance dissolves in water, it gives its taste to the water, so that water in which sugar is dissolved is sweet, alum water is bitter, and so on.

When a coloured substance dissolves in water it nearly always gives its own colour to water. Take a small piece of copper sulphate and dissolve it in water; the water quickly becomes blue. You can easily see that the solution is no longer pure water.

It is not always so easy to tell whether a substance dissolves, specially if it is only slightly soluble. Take, for instance, the case of lime. Powder some lime finely and then pour water on to it in a glass. Stir it well, and allow it to settle. There is still a great deal of lime left in the glass. Has any dissolved? You say that you can tell by the taste. So you can; but it is not safe to taste everything and we must have some other method of finding out.

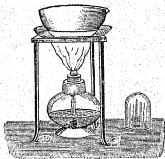
We have already seen that water can pass through a filter. Now, not only water, but all

dissolved substance also, can pass through the holes of porous things. So if we filter the mixture of lime and water, any lime which has dissolved will be found in the filtrate. Filter the lime and water in the same way as you filtered the chalk and water in the last lesson. You see the water comes through quite clear.

Now, if we can drive away the water which has passed through the filter, we shall soon see if any lime is left in the glass. To drive away the water we must boil the solution. We can do this in a shallow vessel made of iron, or copper, but chemists generally use a vessel made of glazed earthenware called an *evaporating dish*.



This is put on a tripod (three-legged) stand and heated with a gas burner or spirit lamp. It is best to put a sheet of wire gauze, or a sheet of thin iron covered with sand, between the flame and the dish. This keeps the dish evenly heated and prevents it from cracking.



When the things are all ready, pour the filtrate into the evaporating dish and heat it gently till all the water has boiled away. Then examine the dish. If you scrape it with the blade of a knife you will get a white powder, which is the lime that had dissolved in the water.

When we filter a solution, all the dissolved substance passes through the filter.

When we evaporate, or drive away the water from a solution, the dissolved substance remains behind.

XIV. CRYSTALS.

Take some nitre, blue vitriol, green vitriol, alum, salt and carbonate of soda. Put a little heap of each on a separate sheet of paper. You will find that in some of your heaps there are small pieces of substance with a glassy look and with smooth even sides. These are called crystals. See if you can pick any such crystals out.

It is quite likely that your specimens have been rubbed and broken in travelling and that you will not be able to pick out any good crystals, so you may set to work to make some. Begin with nitre. Make a strong solution of nitre in boiling water, and divide it into three parts. Pour one part into an evaporating dish to cool slowly. Pour the second

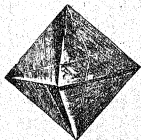
into a test tube and put the test tube in cold water to cool it quickly. Pour the third into an evaporating dish and evaporate it to dryness with the spirit lamp. You will not find any crystals at all without the help of a very strong microscope.

Now examine the test tube which has cooled quickly. There is a white powder at the bottom of the tube, but if you look at the powder through a magnifying glass, you will see the powder is made up of *tiny crystals*.

Now turn to the solution which was put on one side to cool slowly. Notice that the crystals form slowly and are much *larger* than when the solution was cooled quickly.

To make fine large crystals the best way is to make strong solutions of the substances in water at about 50°C .

1. Powder up the substance very finely in a mortar, put it into a bottle and shake it with the warm water till no more dissolves. Then allow the undissolved part to settle and pour off the clear solution into a beaker, or small flask. Put it on one side and examine it the next day, as the water evaporates crystals will form. The more slowly it



evaporates the longer the crystals take to form, but they are larger when the solution evaporates slowly than when it is evaporated quickly.

You know why the crystals separate out as the solution cools. It is because a cold solution cannot dissolve so much as a hot one. And when a solution evaporates, some of the water goes away as vapour and therefore there is not so much water to dissolve the substance and so again crystals separate.

Crystals can sometimes be made without making a solution of the substance. Take some sulphur in a small iron spoon, or cup. Hold the cup with iron tongs and melt the sulphur over a flame. If the sulphur catches fire, extinguish the flame as soon as all the sulphur has melted. You can do this by blowing very smartly. Allow the sulphur to cool slowly and as soon as a crust forms over the top, make two holes in it and pour out the sulphur into cold water. When the sulphur in the iron cup is cold, examine it carefully. Notice the needle-like crystals of sulphur.

Examine the sulphur that was poured into water. Is it crystalline?

Many substances crystallize from their liquid state on being cooled. Such things are tin, lead, wax, and the crystals which are often found in rocks.

Collect the various crystals which you have made, keeping them separate from one another. Dry them carefully by pressing them between blotting paper. Note their different shapes and colours. Put them away. You will need them again.

XV. MIXTURES AND COMPOUNDS.

A Mixture.—Take some iron filings and some finely powdered sulphur and mix them together. The best way to mix them thoroughly is to rub them together in a mortar by means of the pestle. You have now made a mixture of iron and sulphur. Can you separate the two substances from one another again? Let us see. Get a magnet and move it about through the mixture. The small particles of iron quickly come away from the sulphur and stick to the magnet. It is very easy to separate the two.

A Compound.—Now mix the iron and sulphur once more, taking about twice as much sulphur as iron, and this time put some of the mixture on an iron plate and heat it until the sulphur catches fire. When it ceases to burn and when the plate has cooled, try to remove the iron filings again by means of the magnet. You cannot do so. Break up the mass of stuff on plate and powder it in the mortar. Now try again with the magnet. No,

you cannot take the iron away. The iron and the sulphur are no longer simply mixed together; they have *combined*, and formed a **compound**. The compound is a *new substance*. It has quite different properties from either iron or sulphur, and it is called *sulphide of iron*.

We will take another example of the difference between compounds and mixtures. Powder up together in the mortar some ordinary sand and sugar. Have you made a mixture or a compound? Shake up the mixture with some water in a flask and then pour the solution on to a filter and collect the filtrate in a porcelain dish. The filtrate comes through quite clear. Taste it. It is sweet. Rinse the filter paper several times with a little more water, so as to wash all the sugar down into the dish. You now have all the sugar in the dish, and all the sand in the filter paper.

The sugar and sand had only made a mixture; that was why you could separate them again so easily. You had made *no new substance*. The sugar and sand had not combined.

How would you recover dry sugar from the solution in the dish?

Difference between Mixtures and Compounds.—What, then, is the real difference between compounds and mixtures? Take again some of your

mixture of iron filings and sulphur and examine it carefully with a good lens or magnifying glass. You can distinguish that there are small particles of sulphur and small particles of iron side by side. *The mixture is not one substance throughout.* Now examine the sulphide of iron in the same way. You can no longer see more than one substance under the lens. *The new compound is the same throughout.* It is a single new substance.

Examine the mixture of sugar and sand with the lens in the same way. You will see quite clearly little grains of sand side by side with the particles of sugar.

A compound can only be made by chemical action, a mixture is made by mechanical action. You will learn more about chemical action in later lessons, but you may remember now that chemical action always produces heat change.

Which of the following are mixtures and which compounds:—salt, potassium chlorate, borax, curry powder?

XVI. SOLIDS AND LIQUIDS.

When ice is warmed it turns to water; ice is solid water, or we may say that water is liquid ice. In the same way if you take some wax in an iron

spoon and warm it, the wax will *melt* and become liquid. Lead can be melted in a similar manner, but it will require more heat to change it into the liquid form, or state.

When the lead or wax are cooled again they once more become solids. They had changed their state when they were melted, but they were still lead and wax.

What, then, is the difference between the solid state and the liquid state? **A solid is a substance which has a certain definite shape of its own.** You can only alter its shape by bending or breaking it. Take a stone for instance. The stone will always have the same shape, no matter where you put it. On the table, on the floor, in a glass, in your hand, it still has the same shape. But now consider a liquid. Water is the simplest example. Pour a little water on to the floor. It runs all over the floor. Pour some into a glass; it takes the shape of the glass. Pour some into a *lotah*; it takes the shape of the *lotah*. **A liquid flows, and takes the shape of any vessel into which it is poured.**

There is yet another difference between solids and liquids. You can break up a stone into powder, but you cannot make the powder run together again to form a stone. Yet if you break up a liquid, it will form small round drops, and these drops readily

run together again. Then, again, when it is at rest the surface of a liquid is always level, or horizontal, but, of course, that is not the case with a solid substance.

Solids and liquids resemble one another in one respect. You have seen already that a solid keeps its own shape. It also keeps its own *size* unless it is heated, or cooled. Although a liquid does not keep its own shape it also keeps its own *size*. If you pour water into a glass, and then from the glass into a flask, the size of the water in the flask, that is its volume, is the same as its volume in the glass. Solids and liquids then, although they differ in many ways, are alike in having a size of their own.

XVII. GASES.

Substances, at least many substances, can exist as solids, and as liquids as well. Some solids and nearly all liquids can exist in a third state. They can become *gases*.

When water is boiled, as you know, it passes away in steam. When the steam gets into cold air it forms a kind of white cloud, which really consists of tiny drops of water. You can see this cloud quite plainly. But put a little water into a glass flask

and boil the water in that ; the air will soon be driven out of the flask and all the space above the boiling water will be filled with steam. Now you see that the steam is just as transparent as air is.



What will happen if the steam is cooled ? Let us cool a little and see.

First stop heating the flask. Then lower the end of a cold glass rod into the flask and take it out carefully so as not to touch the sides of the flask or the water in the flask. You see that it is covered with water. The gaseous steam has condensed into water again.

Ordinary air is another gas. Let us consider some of its properties. Take an empty flask and hold it upside down and dip the open end under water. Why does not the water rush in and fill the flask ? You say the flask was full of air. Yes, it was not really empty at all. Air has no form or shape, it takes the shape of the vessel into which it is put but it is different from a liquid because it has no skin, or *surface*.

If you have a bicycle, you know, that air can be

compressed very much. A bicycle tyre is full of compressed air, and when you use your pump you are compressing air into a smaller space than it occupied before. That is very different from water. You cannot compress water however much you try. So air differs from water in that it has no definite size. Its size can be made larger, or smaller. A gas can flow and spread out in any direction. If you take a few drops of ammonia solution and warm it, some of the ammonia gas will escape. Very soon the whole room will smell of ammonia, so that the gas has passed into every part of the room. A gas has no definite size, or shape of its own ; it has no surface, and it can flow in every direction.

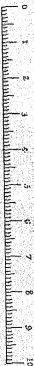
Write down the differences between solids, liquids and gases. What substances can you mention which can exist as solids and liquids ; what as liquids and gases ; what as solids, liquids, and gases.

XVIII. MEASUREMENT OF LENGTH.

If you are asked what is the length of the table at which you sit, you will say it is so many *gaz*, or *gira* or *inches*, say 2 *gaz* or 32 *giras*, or 72 *inches*. Two things are necessary to tell us the length of the table, namely, a number, and a unit ; the number 32 and the unit the *gira*, or the number 2 and the unit the *gaz*, or the number 72 and the unit the *inch* ; if you were told the length of

the table was 32, you would be no wiser until you knew what the unit was.

There are many different units used in different countries for measuring length, but it is not convenient in science to have a lot of different kinds of units to measure the same thing. Hence for measurement of length, in science, one unit is chosen. It really does not matter very much what unit we take for our measurement, but the easiest one to use is the French unit, the centimetre. This unit and the multiples of it are easy to use, because they are always multiplied or divided by ten to get to the next unit. Thus ten millimetres make a centimetre, ten centimetres make a decimetre, ten decimetres make a metre and so on.



In the margin is shown a scale 1 decimetre long. It is divided into centimetres and millimetres. You see that it is 10 centimetres or 100 millimetres. The numbers 1, 2, 3, &c., are centimetres. Below is a table of the metric system (as this system is called) of lengths—

10 millimetres	= 1 centimetre.
10 centimetres	= 1 decimetre.
10 decimetres	= 1 metre.
1,000 metres	= 1 kilometre.

All you need learn now is that a kilometre is 1,000 metres, and that a metre is 100 centimetres or 1,000 millimetres.

The English unit of length is the inch. By comparing an inch with a centimetre we find that there are 2·54 centimetres in one inch. If we know the length of anything in centimetres we can find its length in inches by dividing by 2·54. A *gira* is 2·25 inches or 6·35 centimetres.

Exercises.—(1) Measure the length of the table in centimetres, inches, and *gira*.

(2) How many centimetres are there in one *gira*?

XIX. MEASUREMENT OF AREA.

When we have fixed our unit of length we have also fixed our unit of area without any further difficulty.

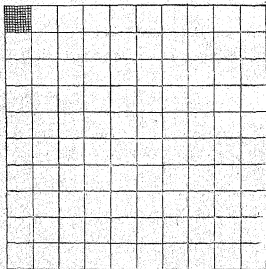
If we take the centimetre as our unit of length, our unit of area will be the square centimetre. A square centimetre is the area covered by a square of which each side is one centimetre.

100 square centimetres make a square decimetre; that is, if we make a square of which each side is a decimetre, the area in square centimetres will be 100.

This you can prove by drawing a square of which each side is one decimetre. Then divide each side into 10 equal parts. Each part will then be 1 centimetre.

Now make parallel lines as in the figure, and you will have a number of little squares, each of which will be one square centimetre.

Count these squares. How many are there ?



In the same way 1 square metre
 = 100 square decimetres.
 = 10,000 square centimetres.

✓ If we wish to find the area of a rectangle, we must find out how many square centimetres it covers.

Cut out a piece of paper 3 centimetres long and 2 centimetres wide and place it over the figure. How many little centimetre squares does it cover? You will find it covers *six*.

Do the same experiment with a piece of paper 5 centimetres by 4 centimetres.

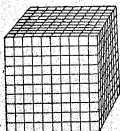
You learn from this that to find the area of a rectangle you must multiply length by breadth. Of course you must use the same unit in each case. You must not multiply decimetres by centimetres or by metres, because then you would be using different units.

Exercises.

- ✓ (1) Find the area of a post-card
- ✓ (2) What is the area of a field 100 metres by 1,500 decimetres? Answer in square metres.
- ✓ (3) A *bigha* is a square whose sides are each 40 gaz. 1 gaz = 91.4 c.m. How many square centimetres are there in 1 *bigha*? How many square metres are there in two *bighas*?
- ✓ (4) The area of a table is 5 squares metres. One side is 1,250 centimetres. How long is the other side?
- ✓ (5) What is the area of your playground?

XX. MEASUREMENT OF VOLUME.

You have already seen that we get our unit of area from our unit of length. Just in the same way we get our unit of volume from the centimetre.



The unit of volume is a little cube, the length of each side of which is one centimetre. This unit of volume is called a cubic centimetre and is written 1 c.c. for short.

For large volumes another unit called the litre is sometimes used. A litre is one cubic decimetre, that is, a cube whose sides are each 10 centimetres long. A litre contains 1,000 c.c.

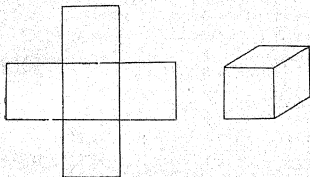
Cut 10 blocks of wood each 1 centimetre thick and 10 centimetres square.

Each of these blocks can be cut up into 100 square little cubes, each of which is a cubic centimetre; and since ten of these blocks are necessary to make up a cubic decimetre or litre, a litre must contain $10 \times 100 = 1,000$ c.c.

In the picture, all the blocks are in a heap, but

the top one has been marked as if it had been cut up into 100 parts, count them. If you make one of the blocks out of wax, or soap, you can easily cut it up into 100 little cubes for yourself.

It is necessary for you to get used to the volume of a litre, and to be able to tell roughly what are the volumes of different substances which you see.



Let us make a litre box out of some stiff paper. Take a sheet of thick paper. On this with the metre scale and a pencil, mark two parallel lines 30 c. m. long and 10 c. m. apart. Divide the long lines into 3 parts, each 10 c. m. long. Then draw two more lines, each 30 c. m. long and 10 c. m. apart, at right angles to these, so that you will have a figure as shown in the illustration. Then cut this cross out with a sharp knife and fold it into a cube. Join the edges with a little thin paper and paste. Each side is now 10 c. m. long.

The volume of the box is one litre. Your teacher will show you a similar box made of tin. If you fill this box with water you will have a litre of water inside the box.

Pour out a litre of water into a large tumbler and note how far it is filled.

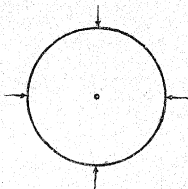
Find out how many times you have to empty a small bottle into the litre box to fill the latter and calculate how many c. c. the bottle holds.

XXI. WHAT IS WEIGHT?

If you try to lift up a big stone you will find that it is difficult to lift it. You will have to try hard to lift it off the ground; if you let it go, it falls to the ground again. If the stone is very big you will not be able to lift it at all. It seems as if the stone wanted very much to lie on the ground, but it is really not on the surface that it wants to lie. If you dig a hole in the ground and let a stone fall into it—say down a well—the stone will fall, not to the surface of the ground but right down to the bottom of the well.

We know that the earth is round like a ball, because we can travel right round it in one direction and come back to the same place. People in one part of the earth are standing with their feet

towards our feet. Now no matter on what part of the surface of the earth we may be, we find that stones fall straight down, that is, they always fall towards the centre of the earth.



This is what we mean by saying that the earth attracts, or pulls bodies towards itself, and the pull is always towards the centre of the earth. This attraction, or pull of the earth, on bodies is what we call their *weight*. Another name for the attraction of the earth is "the force of gravity."

(1) The attraction of the earth ; (2) the pull of the earth ; (3) the force of gravity ; and (4) the weight of a body ; all mean the same thing. It is because the pull of the earth is towards its centre that we are able to stand up straight everywhere, and the people on the opposite side of the earth,

with their feet towards our feet, do not fall away from the earth.

The force of gravity is different for big stones and for little stones, as you can see by lifting, or trying to lift them. For big stones the force of gravity is large, for little stones it is small, or the weight of big stones is greater than the weight of little stones.

For the same stone the force of gravity, that is, the weight of the stone, is greatest just at the surface of the earth. If we lift the stone up to the top of a tower the stone gets lighter, but only so very little lighter that you will not be able to tell the difference by feeling the weight of it in your hand. If we take the stone down a well, too, it will get lighter.

This may seem strange to you at first, but you will easily see why it is so, if you think that every little bit of the earth helps in attracting the stone. When we take the stone down a well, then some of the earth is pulling it up instead of down and so the attraction is less.

If we could dig a hole right to the centre of the earth, we should find that there the stone has no weight at all. All the different parts of the earth are then pulling it equally in every direction. There is then no pull in any one direction. That

is, the stone has no weight. At the centre of the earth a big stone would be just as easy to lift as a little one, and you could easily lift a horse there, but you will never be able to try, because we cannot dig so far ; it is about 4,000 miles or 6,400 kilometres to the centre of the earth. Also it would be too hot to live there. We are able to measure the shape of the earth, and we find that it is not exactly round, but that it bulges out more in one part than another.

For this reason the force of gravity, or the weight of a body, is not the same at all places on the surface of the earth. At the places which bulge out it is less than at other places, and it is a very important experiment in physics to find the force of gravity in different places. India is placed more on the bulging part of the earth than England ; hence the force of gravity is less in India than it is in England. Therefore it is easier to lift stones and jump high in India than it is in England, but only so little easier that you would never notice the difference.

XXII. RELATIVE DENSITY.

You can see for yourself that most things have weight. There are some things, however, which do not seem to be attracted to the earth. For instance, light bits of paper and dust fly about in the air and do not fall to the ground.

Have such things no weight, or does the earth push them away instead of attracting them?

All bodies, bits of paper, dust, and even balloons, have weight. Even air has weight. Dust and light bits of paper fall to the ground slowly when there is no wind to blow them about. They are a little heavier than air. If they were exactly as heavy as air they would neither move up, nor down, but would remain in the same place till carried away by the wind.

Boys are very fond of watching fire-balloons, but they do not often ask the question, "Why does the balloon rise in the air?" What is the answer to this question?

Has the balloon no weight? Does the earth

not attract balloons? Yes, balloons have weight, and the earth does attract them.

Let us try to answer these questions by another experiment. Take a cork and hold it in a pair of tongs. Open the tongs; the cork drops to the ground. The cork has weight.

Now take the cork up again in the tongs and plunge it under water in a large *gharra*. Open the tongs: the cork rises to the top of the water and floats there.

Why? Because the cork is lighter than water. Now, you can tell why a balloon rises in air. Because it is lighter than air. That is the correct reason. If it was heavier than air it would fall to the ground.

You have seen that a cork floats on water, and you know that wood and straw also float. You know that lead will sink; even if you take the smallest piece of lead it will sink in water. Why is this? You say that lead is heavier than water and so it sinks. That is partly true but not quite true. A seer of wood weighs just as much as a seer of lead, no more and no less. "Yes," you say, "but there is more in a seer of wood."

"More what?"

“The seer of wood is bigger, it takes up more room.” Yes, that is right. When you said that air is heavier than balloon, and that lead is heavier than wood, you were comparing *equal* volumes of the things you mentioned. The correct thing to say is that lead is denser than wood, that water is denser than cork, and that air is denser than the balloon.

XXIII. WORK AND ENERGY.

When we lift up any body we do so against the force of gravity and we are said to do work. Thus we do work when we lift water from a well, or when we get up into a *gari*, for to do so we must lift our bodies against the force of gravity. Again when we take a walk, we do work; for when we walk, our bodies are constantly moving up and down. When we move our bodies up we do so against the force of gravity. That is, we do work. This work, which we are thinking of in this lesson, is labourer's work, not brain work such as we do when we learn our lessons. That which we have in us, which makes us able to do work is called energy. When we get ill our energy becomes less, so we are not able to do much work.

Animals are able to do work like ourselves. Thus they can draw water from a well and can pull carts, and that which enables them to do work is energy too. When they get ill their supply of energy becomes less, so they, too, are not able to do so much work.

Machines, too, are able to do work. They can be made to pump up water from a well, or to pull a train, or to drive a motor car. When they

get out of order, they are just like us when we get ill, they are not able to do so much work. Since machines are able to do work, this work we are speaking of is called mechanical work.

Let us think of a simple machine which is able to do work.

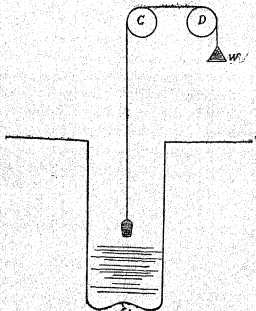


Fig. 1.

Here is a picture of one. We have a heavy weight W raised some distance from the ground. Attached to it by means of a rope passing round

two pulleys C and D, we have a bucket at the bottom of the well. If the distance from the weight to the ground is equal to the depth of the well and if the weight is heavier than the bucket, full of water, then the weight will fall to the ground and draw the water up to the top of the well.

The weight in this case does work and when it is up at the top, it has energy; when it falls to the ground its energy is gone, but it has done work in lifting up the bucket of water.

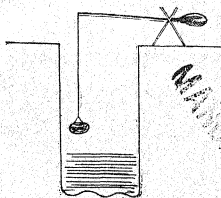


Fig. 2.

The lump of mud in a *dhenkli* has energy when raised up in figure 2. When it falls down its energy is gone but it has done work in raising the water from the well.

Energy is the power of doing work. It is indestructible, that is, it cannot be destroyed without getting something which is equal to it in the form of work. You can change energy into work just as you can change water into steam, but you cannot destroy energy any more than you can destroy water, you can only change it. Matter and energy are the two indestructible quantities in nature, but you must not think that they are the same thing. Energy cannot be weighed, and it is, therefore, not a substance like the substances you read of in chemistry. In other words, energy is not matter.

XXIV. MORE ABOUT ENERGY.

In the last lesson you saw how a heavy weight at some distance from the ground could do work and thus has energy; there are different kinds of energy to which we give different names.

We saw that when the weight was raised up from the ground it had energy, but when it reached the ground its energy was gone. In place of it we got a certain amount of work in the lifting up of the water; the energy was not lost but changed into work. The energy which the weight had when it was raised off the ground is called potential energy, or energy of position.

We said in our previous lesson that energy cannot be destroyed, it can only be changed into work. Now consider what happens to the potential energy of the weight W in the previous lesson, if instead of drawing up a bucket of water we cut the rope and let the weight fall. Does all the potential energy disappear without doing work?

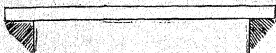
No, energy is indestructible. What happens is this:—the weight begins to fall at first slowly, then faster and faster until it is just close to the surface of the ground. In this position the potential energy has all disappeared but another kind of energy has appeared in its place. This second kind of energy is the energy of motion of the weight and is called **kinetic energy**. Just at the surface of the ground this kinetic energy, or energy of motion of the weight, is exactly equal to the potential energy of the weight, before it began to fall. The potential energy of the weight, before it began to fall, has not been lost, it has only changed into kinetic energy.

It still remains energy, but of a different kind. But now an instant later the weight thumps hard on the ground and is brought to rest. It has no motion now and so it has no kinetic energy, also it has lost its potential energy. Has energy been destroyed now? No, look at the ground under the

weight and you will find the weight has dug a hole in the ground. Now, to dig a hole in the ground work must be done, and so the kinetic energy has not been destroyed, it has been changed into work.

If you try to bore a hole in a piece of wood you will find you do work. Now fire a bullet at the piece of wood. The bullet will bore a hole in the wood. The energy of motion of the bullet has done work, and its kinetic energy has been lost.

Take a plank of wood which you can just bend but cannot break. You will find that you have to



do work to bend it ; more work still will be required to break it. Now support it, as shown in this figure, and throw a heavy stone at the middle of it. The stone will probably break the plank. Here again kinetic energy has been changed into work. The stone is brought to rest and the plank is broken.

XXV. HEAT.

Place a can of cold water on the fire and from time to time place your hand in it. After it has been on the fire for a little while, you will feel it hot, and you will also feel that it is getting hotter and hotter, the longer you leave it on the fire.

Now take another can of cold water and put a big lump of ice in it. Keep stirring it and put your hand in it from time to time. You will find it cold at first and you will feel it getting colder and colder as long as there is any ice left. Heat and cold are two feelings which we cannot explain to any one who has never felt them. Yet we know well what they are like, when once we have felt them ourselves and we would never mistake them for another feeling such as heaviness, or roughness, or smoothness.

Now what *are* hotness and coldness? Are they different things, or the same thing looked at differently? They are really the same thing looked at differently, as we shall now explain.

Experiment I.—Take two equal pieces of iron and place one in a can of hot water and the other in a can of cold water and leave them

there for about two minutes. Now when you take them out, of course one feels hot and the other feels cold. Put them together on a piece of wood so that they touch one another, and leave them for about two minutes more. On touching them again you will find that the hot one has become cooler and the cold one has become warmer.

This shows us that heat passes from a hot body to a cold one.

Experiment II.—Now take three cans like those used in the last experiment, containing—

- (1) Water just about as hot as you can keep your hand in.
- (2) Very cold water.
- (3) Water neither hot, nor cold.

First put one hand, say your right hand, into the hot water and your left hand into the cold water. Keep them in the water for about a minute. Now take your hands out and put them both into the can of water which is neither hot, nor cold, and you will find that to your right hand the water feels cold and to your left hand the water feels hot.

Now if we remember that heat passes from a hot body to a cold one, we see from this experiment

what hot and cold really mean. If heat passes from any thing we touch *to* our hands we say that the thing is hot. If heat passes *from* our hand to the thing we touch, we say the thing is cold. Heat and cold are not quite different. At one time a thing may feel hot and at another time cold. The feelings depend on the state of our bodies which causes us to look at heat and cold differently at different times. They are both due to the flow of heat; in one case to our bodies, in the other case from our bodies.

XXVI. EVAPORATION. ✓

If you pour some water into an open dish and leave it for a few days, you know that it dries up and disappears. The hotter and drier the weather the more quickly it goes.

You know, too, that when you heat water, it boils away. The liquid turns into a vapour, or gas. A liquid will turn into gas without being boiled, but the warmer the liquid is made, the more quickly it becomes a gas.

This change, from liquid to gas, or vapour, is called **evaporation**.

Now, if warming a liquid makes it evaporate,

you may wonder why liquids evaporate, when they are not made warm. The reason is this :—

Air has the power of sucking up water into it. Wherever dry air touches water, some of the water will begin to turn into vapour and pass into the air. Hot air can hold more water vapour than cold air, and can take it up more quickly. In this respect air behaves very much like water. Water will dissolve more sugar when it is hot than when it is cold. When it has dissolved a certain amount, it becomes saturated and can dissolve no more. Just in the same way, when air has taken up a certain amount of water vapour it, too, becomes saturated and it can take up no more. That is why evaporation is so slow in rainy weather. The air contains a great deal of water vapour and so can only take up very little more.

If you cover up water in a beaker by means of a larger beaker placed upside-down over it, there will be hardly any evaporation at all. The air round the beaker will soon become saturated with vapour and all evaporation will stop.

If you put water in a flat dish so that a current of dry air passes over it, the evaporation will take place



rapidly, because the current of air takes away the vapour with it. Then fresh, dry air goes over the surface of the water, in the place of that which has taken up vapour, and this dry air can take up more vapour, and so on.

XXVII. DISTILLATION.

You have learned that when water is boiled it changes into a gas which we call steam.

What happens when steam is cooled ?

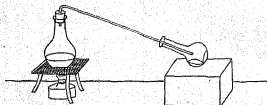
Boil a little water in a long test tube. Notice that at the open end of the tube, little drops of water form. The hot steam changes back into water again, as it cools.

The change of steam into water, or of any vapour into liquid, is called **condensation**. Water vapour from the sea, rivers, and ponds rises into the sky and is cooled there; it condenses into water, forms clouds and falls again as rain.

In chemistry we make use of this property of condensation a great deal. Ordinary water generally contains some dissolved impurities and we cannot get rid of them by filtration, because

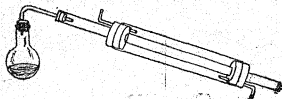
dissolved substances can pass through the filter. To purify water from dissolved substances, we use a process called **distillation**. The dissolved impurities cannot change into steam and so remain behind when water is boiled.

Take a flask and fit it with a cork and long bent tube as in the figure. Pour some water into it and add a little sand and some ink to the water. The water is now dirty and impure.



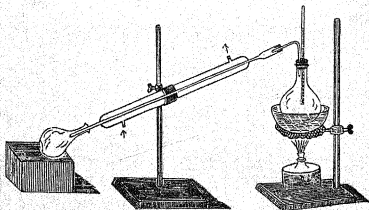
Place the free end of the tube in a second flask and boil the dirty water. Steam forms and begins to condense in the tube, then drops form and fall into the second flask. After the water has been boiling for a few minutes the tube and collecting flask have become so hot that no more steam condenses. It comes out into the air. To make the steam condense, we must keep the flask and tube cool. We can cool the flask by putting it into

cold water, or pouring cold water over it; but if we put the flask into cold water, the cold water will soon become hot, and to keep on pouring cold water over the flask would be very troublesome.



The best way of cooling the steam is by means of a *condenser*. This has an inner tube for the steam, and an outer jacket for cold water. Condensers are made of glass or tin. If you get a hollow tube of tin about eighteen inches long and an inch and a half in diameter, you will easily be able to make a condenser for yourself. Put a double bored cork at each end and through the two corks pass a long straight tube. Next, into the second hole of each cork pass a small bent tube. One should bend upwards, and one downwards.

Now fit the tube from the flask to the condenser, if it will pass into the condensing tube, let it do so. If not, join the two with a short rubber tube.

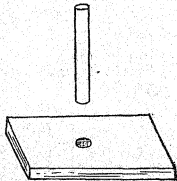


Glass Condenser.

A current of cold water is passed through the outer part of the condenser. This can be done best by connecting the lower tube A to the water tap and allowing a slow stream of water to pass. Notice that the water that escapes at B is warm, also notice that as the inky water boils, the steam which passes over into the flask is all condensed into water. This condensed or distilled water is quite clear and pure; it is no longer inky and it contains no sand. The impurities have remained in the flask in which water was boiled.

XXVIII. EXPANSION.

Take a smooth rod of brass which *just* fits into a hole in a plate of brass. Make the rod very hot in the fire and then try to fit the rod into the hole. You will find that the rod will not fit now ; it has grown bigger owing to the heat.



If you allow the rod to cool, you will find it again fits the hole, so that the rod only remained bigger while it was hot.

Again, take a tube AB of 15 m.m. internal diameter with another tube BC of 3 m.m. internal diameter, attached to it. Fill it with water up to some point C. Make a mark on the tube at C,

and then dip the tube into a vessel of very hot water. You will see that the water runs up the tube BC.



The water, like the brass rod, has increased in size (that is in volume) owing to the heat. On letting it cool, or dipping the tube BA into cold water, the water in the tube will run back to its original position.

Now pour the water out of the tube and leave only a little drop of water in the fine tube. To keep it there you must hold the tube horizontal. The tube is now filled with air and is closed with a stopper of water which will move easily. Now hold the end AB over a flame, the water will run towards the mouth of the tube. This shows that the air has increased in volume owing to the heat. Now pour cold water over the tube and the drop of water will run back from the mouth, showing that cold makes the air contract.

We see then that brass, water and air (a solid, a liquid and a gas), increase in size, or volume, when heated, and decrease in volume when cooled. This increase in size is called *expansion* and the decrease in size is called *contraction*. Hence we say that brass, water and air expand when heated and contract when cooled.

Expansion means growing larger.

Contraction means growing smaller.

Nearly all substances expand when heated and contract when cooled.

XXIX. TEMPERATURE—(1).

In this lesson we shall study the meaning of temperature.

Take two glass tubes—a big one A and a small one B. Connect them together with a piece of rubber tubing C. Fill them about half full with water. Hold the two tubes together. You will see that the water stands at the same level in both tubes. There is more water in B than in A, because it is bigger than B, but the level of the water is the same in both.

Now get some one to pinch the rubber tube hard, so that water cannot flow from one tube to the other. Now lift B a little higher than A and tell the person to let go the rubber



tubing. You will see the water flows from B to A till the level of the water is the same in both tubes. There was more water in A than in B, but still the water flowed from B to A, because the level of the water was higher in B than in A. If you raise A above B, water will flow from A to B till the level of the water is the same in both the tubes.

This experiment teaches you that water always flows from a high level to a lower one.

Now take two pieces of iron or brass—a big piece and a little piece. Hold the little piece in a pair of tongs and heat it in a flame, or fire, till it is so hot that you cannot touch it. Now place it on a piece of stone and put the big piece on the top of it. After a little while you will find the little piece has become cool and the big piece has got warmer. They both feel equally warm after a little while. But the big piece may have more heat in it than the little piece, because it is bigger. But yet heat passed from the little piece, to the big one.

This experiment on the flow of heat is just like the one on the flow of water that you did at the beginning of this lesson.

Water always flows from a high level to a lower one. In heat, temperature is like water-level in the motion of water. Heat always passes from a body at a high temperature to one at a lower

$$Q = \frac{T_1 - T_2}{R_{th}}$$

temperature. In the heat experiment you have just performed, the quantity of heat in the small piece of iron is like the quantity of water in the small tube. It may be less than the quantity of heat in the big piece of iron. But if the temperature of the little piece is greater than the temperature of the big piece, heat passes from the little piece to the big one.

You see that heat passes from a hot thing to a cold one. What we mean by a hot thing is one at a higher temperature than our bodies and a cold thing is one at a lower temperature than our bodies. One may possess more heat than another and yet have a lower temperature: heat would then pass from the hotter thing to it, just as in the two tubes of water, water flowed from the small tube B into the large tube A, when the water level in B was higher, although A had more water in it than B.

XXX. TEMPERATURE—(2)

The word used in science, instead of hotness and coldness, is temperature.)

How are we to measure how much one thing is hotter than another? We can do so by feeling them. But by feeling alone we are not able to judge very accurately how much hotter one thing

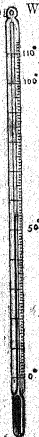
is than another. We must invent some instrument to help our senses of feeling in measuring temperature.

What instrument would you invent? Think of what you learnt in your lesson on expansion and you will think of the right instrument at once. When bodies are heated they expand. A rod of brass, for example, always expands when heated and contracts when cooled. It always has the same length at the same temperature. Therefore you might employ a rod of brass to measure temperature and you would know its temperature when you knew its length.

But liquids expand more than metals when heated to the same temperature. Liquids are, therefore, better substances than solids to use for measuring temperature. The best liquid to use is mercury.

The instrument used for measuring temperature is called a thermometer. A thermometer is a very fine glass tube with a bulb at one end containing mercury.

When you warm the bulb the mercury expands and rises in the tube ; when you cool the bulb the mercury contracts and



falls in the tube. At the same temperature the end of the mercury is always at the same point on the glass tube. If you take the thermometer from one can of water and put it into another and if the mercury rises in the tube, you know that the water in the second can is hotter than the water in the first can. If the mercury falls in the tube, the water in the second can is colder than the water in the first can. By this means you will be able to see that one can of water is hotter, or colder, than another, although you might not be able to tell the difference by putting your hand in them.

XXXI. DEGREES OF TEMPERATURE.

Up till now you have only seen how to tell if one body was hotter, or colder, than another. You have not learnt how to find out how much hotter, or colder, it is. To be able to tell how much hotter, or colder it is we want some scale which we can read. This scale is called **degrees of temperature**. *The scale for measuring how much hotter or colder than*

We shall now see how to get our degrees of temperature.

There are different scales to measure lengths. For example, there are centimetres, which is one scale and it is the scale we use in science. There

are also inches, which is another scale. There are also *gaz*, which is a third. In measuring temperature there are also different scales. In science the scale used is called the centigrade scale. This scale is made just as the centimetre scale was made.

How was the centimetre scale made? A rod of platinum had two marks made on it and the distance between the two marks was divided into one hundred equal parts. Each of these equal parts is called a centimetre. To make the centigrade scale of temperature we do just the same. First we take two fixed points of temperature and then we divide the distance between these two points into 100 equal parts. Each of these parts is called one degree centigrade.

We only need now to choose our fixed points. We know that pure water always freezes at the same temperature. It also always boils at the same temperature in the same place. It boils at lower temperatures as we ascend a mountain, but just at the level of the sea it always boils at the same temperature. The freezing point and the boiling point of water are therefore very good points to choose for our fixed points.

Take a thermometer, that is, a glass tube with a bulb containing mercury, and place it in melting ice. When the end of the mercury has stopped

moving, make a mark on the glass just where it stops. Now place the thermometer in water boiling near the level of the sea and when the end of the mercury has stopped moving, make another mark on the glass tube. These two marks are our fixed points. Divide the distance between the two points into 100 equal parts and we have degrees centigrade.

XXXII. CONDUCTION OF HEAT.

Take a rod of iron, or brass about half a metre long. Hold one end in your hand and put the other end in the fire. Keep it there for some time. After a little while you will feel the end you hold getting warmer. It will soon become so hot that you may not be able to keep it in your hand. When you put one end of the rod in the fire that end very soon becomes nearly as hot as the fire. Heat then passes from this hot end to the colder parts of the rod, because they are at a lower temperature. When heat passes along as it does in this experiment, it is said to be *conducted* along the rod, or the heat is said to pass along the rod by *conduction*.

Now take two rods of the same length, one rod of iron, or brass, the other rod of wood. Take care that they are both cool to start with. Hold one end of the iron rod in one hand and one end of the wooden rod in the other hand. Put the other ends

into the fire quite close together. The two ends that you hold in your hands will become hot after a little time. But you will find that the iron rod becomes hot much quicker than the wooden rod. The ends that are in the fire are both equally hot, the wood is very likely burning. But still the end of it that you hold in your hand is not as hot as the end of the iron that you hold in your hand.

This experiment shows you that heat is conducted along a piece of wood just as it is conducted along a piece of iron. But the heat is not conducted along the wood as quickly as it is conducted along the iron. Wood, then, is said to be a worse conductor of heat than iron. Or iron is a better conductor of heat than wood.

All things conduct heat, but they are not all equally good conductors. Iron, brass, tin and all metals are good conductors of heat. Wood, glass and stone are bad conductors of heat. Wool is also a bad conductor of heat. That is why a woollen blanket keeps us warm on a cold night. It keeps the heat of bodies in, or it is more correct to say it conducts it away only very slowly.

XXXIII. LIGHT—HOW DO WE SEE?

We come to know all things by means of our senses. The senses are five in number. They are seeing, hearing, feeling, tasting, smelling. Of these the greatest and most important of all is seeing, or the sense we possess owing to the peculiar power of our eyes. We can see only with our eyes, we cannot see with any other part of our bodies. We see with our eyes, because there is something which can pass through our eyes, and make pictures at the back of them. That something which can pass through our eyes and make pictures at the back of them is called **Light**.

Light affects our eye only; it does not affect our ears, or any other part of our bodies. That which we see is always light. This may seem strange to you at first. You will say, I can see the book which is before me and the printing on it. True, but why do you not see the book and the printing on it at night in the dark? The answer is because there is no light. When there is light we see things, when there is no light we cannot see them. What we see then is light.

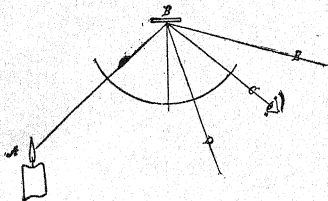
People long ago thought that light was something which went out from our eyes and struck the

thing we looked at, just as we put our hands out and feel things. It was very foolish of people to think that, because, if that were so, we should be able to see in the dark. What do we mean when we say we see a book? We mean that we see the light which comes from the book.

Light is not given out by the book itself; if it were, we should be able to see the book without the aid of a light at night. Light is given out by the sun itself, it is also given out by a lighted candle and by a fire or by anything which is intensely hot. It is not given out by the moon itself. There are two ways in which we may see things,—we may see them as we see the sun, or a fire, or a candle, or a red-hot bar of iron, when they give out light themselves, or we may see them when the light of the sun, or a lamp shines on them. We can see the moon because the light of the sun shines on it.

When light from the sun, or from a lamp falls on anything, two different things may happen. Firstly, we may see the sun itself, or the lamp itself. Secondly, we may not see the sun, or the lamp, but only the thing on which the light falls. Thus if we look at the light from a lamp falling on a looking glass, we see the lamp itself. If we look at a book on which the light of a lamp falls we can see the book itself, but we cannot see the lamp. In the

first case the light is said to be *reflected* by the looking glass. In the second case it is said to be *scattered* by the book.



When light is reflected, it is thrown from the looking glass, in one direction only. Let the light from a candle A fall on a very small looking glass B. Then you can see the candle, if you look at the looking glass in the direction CB. If you look in the directions DB or EB you will not see the candle. You will be able to see the looking glass itself however, no matter from what point you look in.

If the light falls on a book you will be able to see the book, no matter from what point you look. You will not be able to see the lamp by looking at the book.

Thus the book scatters light, but does not reflect it. We know that the looking glass reflects light as well as scattering it, because when we look into the looking glass in the right direction we can see both the lamp and the looking glass. The reflection takes place in one direction only. The scattering takes place in all directions. We see things which do not give out light of themselves, because they scatter the light which falls on them.

XXXIV. THE SPECTRUM.

A piece of glass of the shape shown in figure 3, is called a *prism*.



Fig. 3.

If you look straight down on the top of it, you will see it has a triangular end like figure 4.



Fig. 4.

Take a prism and look at a candle through it; you will see different colours.

Take a sheet of tin about 20 c.m. square and bore a small hole about 1 m.m. diameter in the centre of it. Put it up so that sunlight falls on it as shown in figure 5.

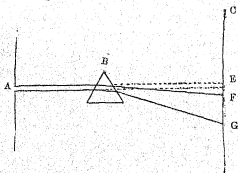


Fig. 5.

Place a sheet of white paper up at C so that the light from the hole in A falls on C. You will see a round patch of white light on the screen C at E.

Now put the prism up between A and C as shown at B.

You will now see that the white patch has been bent away from E and has been drawn out into a streak of light FG which is of different colours.

The colours from F to G are red, yellow, green, blue and violet. *GF.*

Put up a candle behind the screen A and shut out the sunlight. You will see the same streak of colours. *GF.*

This streak of colours is called a spectrum. The white light from the sun, or a candle, is not a single pure light. It is made up of the different colours you see in the spectrum. When these colours pass through a prism they get bent out of their former direction. This bending is called *refraction* and the light is said to be refracted in passing through a prism. Violet light is more refracted than blue. Blue is more refracted than green, green more than yellow and yellow more than red. Hence the light is spread out into the coloured ribbon, which we call the spectrum.

You will say that if white light is made up of the different colours you see in the spectrum, then if you mix all these colours together you will get white light. That is quite correct. Do the experiment for yourself.

Spectrum, How light is made up of different colours.

Take a circular piece of cardboard, the same size as shown in the figure 6 and paint it with the

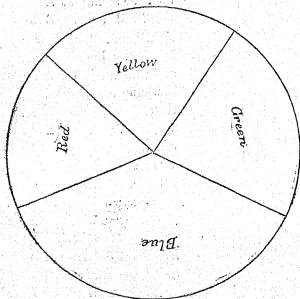


Fig. 6.

colours as shown in figure 6. Make two holes in the cardboard as shown at A and B in figure 6, 7 m.m. apart.

Pass a piece of string 40 c.m. long through the

icles as shown in figure 7. This is simply a *phirki* with one side painted red, yellow, green and blue. Now hold the string at A in your left hand and at B in your right hand. Twist the string by tossing the cardboard round and round. When the string is wound up, pull it tight and the cardboard will turn round very fast. Look at the coloured side and you will see a whole white circle instead of several colours. The colours are mixed together by moving so fast and show as white light.

White light is then made up of several colours—the colours of the spectrum.

Now you know what white is. Do you know what black is? When it is very dark go inside your house, shut all the doors and put out all the lights. What colour do you see? You see black. Hence black must be no colour at all, it is merely the absence of light.

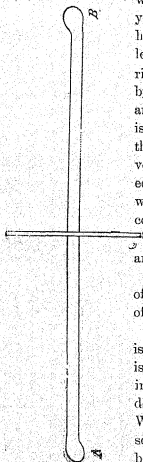


Fig. 7.

XXXV. WHY THINGS ARE COLOURED.

Have you ever thought why things are coloured ? Why is grass green, or yellow ? Why is paper white and ink black ?

You should be able to answer these questions now. You saw in a former lesson that some things scatter light when light falls on them. If the thing on which the light falls scatters all the different colours equally then the thing appears white. The paper of your book then appears white, because it scatters all the light that falls on it. Now all things do not scatter all the light that falls on them equally. When certain coloured lights fall on certain things they soak into the things and do not come back again, they are not scattered at all. They are said to be *absorbed*. When other coloured lights fall on the same things they are not absorbed but scattered.

Thus suppose white light falls on green grass. The white light as you know is made up of red, yellow, green, blue and violet. The green light is scattered by the grass but the other colours are absorbed. Thus you only see the green colour, the other colours do not come to the eye. This is why the grass appears green.

Now why is ink black? You saw in the previous lesson that black is the absence of colour. Therefore, ink must be black because it absorbs all the colours and scatters none.

A blue cloth appears blue, because it scatters blue light and absorbs the other four colours. Now suppose you let red light only fall on a blue cloth. The red light will be absorbed. There is no blue light for the cloth to scatter. Hence the cloth will not scatter any light. But when a thing scatters no light it looks black. Hence in red light a blue cloth should appear black.

Now do the experiment for yourself. The colour of the light from red hot coals is red. If there is no flame rising from the coals there will be no blue in the light. Flame is white and therefore has some blue in it. There must be no flame from the coals. Now look at a piece of blue cloth in the red light of the coals. What colour is it? You see at once it is black.

XXXVI. PROPERTIES OF COMMON SUBSTANCES.

We have now learnt a little about some of the common properties of substances. The next thing is to learn how to examine and describe any

substance by means of these properties. When you describe a substance you must do so as fully as possible, and accurately. To do this it is always best to make the examination in a definite order, and to write down at once the result of each experiment or observation.

1. *Look at the substance.*—Is it solid, liquid or gaseous? Is it coloured or colourless? Is it in lumps, crystals, or powder? Is it transparent, or opaque?

2. *Touch the substance, if a solid.*—Is it dry, or moist? Is it smooth, or rough? Is it soft, or gritty?

3. *Smell the substance.*—Has it a sweet, sharp, or choking smell, or no smell at all?

4. *Never taste the substance* until you have received permission to do so from your teacher, because it may be poisonous. If he tells you to taste it, do so. Has it a sweet, acid or salt taste, or no taste?

5. *Hammer the substance.*—Is it brittle, or malleable? Test whether it is hard or soft. Is it flexible, or elastic?

6. *Dissolve the substance* in water, if possible. Is it soluble in cold water? Is it more soluble in hot water?

7. *Heat the substance* in a test tube. Does it melt? Does it change colour? Does it give off gases, or vapours?

With some of the substances there will be other properties to study as well.

Examine a piece of rock salt and write down its properties in your note book.

Make a crystal from a solution in water.

Break up a piece with a hammer and notice the shape of the small broken pieces.

Draw a crystal.

Your description should, then, tell you that



Salt crystal.

salt is a white crystalline powder, which can form large, colourless, cubical crystals. It is gritty to touch; in wet weather it becomes moist, because it absorbs water vapour from the air. It has no smell, but a saline taste. It is brittle, and on being hammered the large crystals break into smaller parts, often of the same shape. It dissolves in cold water but does not dissolve much more in hot water than it does in cold. When it is heated it makes a crackling sound, which is owing to the larger crystals breaking up into smaller ones. When *very* strongly heated it melts.

Was the rock salt quite colourless? If not, the

colour was due to small quantities of some thing present which was not pure salt. These can be removed by dissolving the salt in water, filtering and allowing the solution to crystallize.

Salt is obtained either from salt mines, salt lakes or the sea. In India a great deal of salt is obtained from the Sambhar lake in Rajputana. The water contains a great deal of salt, which is drawn off into shallow pools and evaporated by the heat of the sun. There is also a great deal of salt obtained from salt mines in the Punjab. Men dig the salt out from the earth and of course it comes out rather dirty and impure. This is purified by dissolving in the water, and allowing the *brine* (which is the name given to a strong solution of salt) to crystallize.

XXXVII. THE PROPERTIES OF BLUE VITRIOL.

Examine blue vitriol in the same manner as you have examined the other substances and write down the results of your observations.

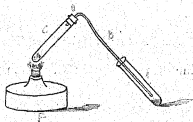
Blue vitriol forms large blue crystals which are brittle and hard ; it has no smell and is poisonous, so it must not be tasted. It is soluble in water giving a blue solution.

The effect of heat on blue vitriol—When you heated blue vitriol in a test tube you must have

noticed two facts. First, the colour of the crystals changed from blue to white and second, vapour was given off which condensed in colourless drops on the cool part of the tube.

If you look carefully at the solid substance left in the tube you will see that besides changing from blue to white, it changes from a crystal into a powder. Evidently some important change has taken place. We must find out what this change is.

Take a large test tube and fill it about a quarter full with some crushed crystals of blue vitriol. Fit



the mouth of the tube with a bored cork in which there is fixed a bent tube, as in the figure.

Under the longer arm of the bent tube place a second smaller test tube.

Hold the larger test tube in a holder.

Now heat the tube containing the blue vitriol, moving it up and down in the flame so as to heat it evenly.

A vapour is given off, which will condense and collect in the second tube. When the blue vitriol has become white stop heating it, and examine the liquid which has *distilled* into the second tube.

If convenient, take its freezing point and boiling point.

You will find that it freezes at 0° and boils at 100° . The liquid is water. You come to the conclusion that *crystals of blue vitriol contain water*. This is called **water of crystallization**. All crystals do not contain water of crystallization; nitre does not, nor does salt. Many crystals do however; for instance, alum, soda, and green vitriol, all contain water of crystallization and they cannot crystallize without it.

Now take the white powder which was left in the tube. Drop some into a little water. It quickly turns blue again and will dissolve to form a blue solution which is exactly like that formed from the blue crystals.

Substances which contain no water are called **anhydrous**, which means *without water*. The white powder is anhydrous.

Blue vitriol contains copper.—Clean the blade of your penknife and dip it into a strong solution of blue vitriol. *How does this prove that blue vitriol contains copper.*

XXXVIII. THE PROPERTIES OF GREEN VITRIOL.

Examine as in preceding cases.

It is extremely likely that the green vitriol in your laboratory looks as if it contained some dirty brown powder mixed with it. If so, powder it and dissolve in *slightly* warm water making a saturated solution. Filter this and re-crystallize. Dry the crystals between blotting paper.

Thus prepared green vitriol forms clear green, brittle crystals soluble in water, giving a slightly green solution. Green vitriol has no smell and should not be tasted.

Effect of heat on green vitriol.—Heat a little of the powdered substance in a dry tube; at first heat gently. Notice that vapour is given off and the green colour of the substance changes to white. The vapour condenses on the cool part of the tube. It is water. Green vitriol like blue vitriol contains water of crystallization.

Now heat the substance more strongly. Thick,

white fumes are given off. These have a pungent odour and obviously are *not* water.

To examine these fumes, fit up exactly the same apparatus as you used for the examination of blue vitriol. Heat some green vitriol strongly in the first tube and collect the *distillate* in a second dry tube. A liquid forms there. Collect some of this liquid. It looks more oily than water and used to be called **oil of vitriol**, although it is not really an oil at all. Dip a glass rod into the liquid and then dip the same end of the rod into a beaker of cold water. Stir it up and taste a drop of the dilute solution. It has a very sour taste. *Do not taste the oily liquid.*

Heat a few drops of the oil of vitriol. Note the white pungent fumes. Place a drop or two on paper, old cloth, and wood. Notice that the oil of vitriol is *very corrosive*. It may even char the wood. Add a little carbonate of soda to some of the oil of vitriol. Notice the effervescence. Add a drop of the oil of vitriol to a little blue litmus solution. It turns red.

Oil of vitriol is usually called **Sulphuric acid**, because it contains sulphur, and can be made from it. Now turn to the tube in which you heated the green vitriol. Take out the residue. It is a brownish powder. Examine this. You find it is

insoluble in water, and is not the *anhydrous* substance.

It looks very much like iron rust.

We must conclude, then, that green vitriol contains water of crystallization which it gives up when it is gently heated; but when the anhydrous substance is strongly heated, it breaks up or decomposes and gives oil of vitriol (sulphuric acid) and a substance which seems like the rust of iron. The chemical name of blue vitriol is *sulphate of copper*; that of green vitriol is *sulphate of iron*.

XXXIX. PROPERTIES OF NITRE.

If the nitre given you is in a powder, prepare some crystals. Notice that they are quite different in shape from those of salt. Your examination will show you that nitre is a colourless, crystalline, dry solid, with a gritty nature. It has a cooling, saline taste. It is brittle. It dissolves in water readily and makes the water in which it dissolves very cold. It is much more soluble in hot water than in cold water.

It melts, when heated in a test tube, and on cooling becomes a white solid again; but it gives off no vapours and it does not crackle like salt.

Nitre is found as a deposit on the soil in parts of Bengal. It is purified by re-crystallization.

It is used as a medicine, and for making gun-powder and fireworks. Mix a small quantity of nitre with a little powdered charcoal in a test tube. Heat it, holding the mouth of the tube *away* from yourself and your companions. Note what happens.

